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FRICTIONAL RESISTANCE IN SLIDING MECHANICS USING DIFFERENT TYPES OF BRACKETS AND ARCH WIRES: AN INVITRO COMPARATIVE STUDY UTILIZING TYPODONT MODEL

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ABSTRACT

Aim: The aim of this study was to assess the effect of different bracket arch-wire interface using conventional elastomeric ligation on frictional resistance during simulated canine retraction on typodont model.

Materials and Methods: The sample consists of three types of brackets: 1- Stainless steel brackets (3M Unitek™) 2- Ceramic brackets (3M Unitek™ Clarity), and 3- Ceramic brackets with metal slot (3M Unitek™). Two conventional uncoated archwires were used: 1- Stainless steel archwires (SS) (ortho organizer), 2- Nickel titanium archwires (NiTi) (ortho organizer) and regular clear elastomeric module were used for ligation. The sample was divided into three main groups according to type of bracket. Majority of investigators used straight length arch-wire and fixed the bracket over models and draw the straight length arch-wire through the but this does not fully simulate the clinical reality, because clinically moving teeth during sliding mechanics do not occur in a straight line. The method used in the present study was designed to closely replicate the clinical situation. All tests were carried out in a dry state on an Instron universal testing machine (crosshead speed: 0.5 mm/min).

Results: Metal slot ceramic brackets generated significantly lower frictional forces than ceramic brackets, but higher significantly values than stainless steel brackets. The highest frictional resistance was observed between Ceramic bracket and NiTi arch-wire combination ligated by elastomeric module.

Conclusion: Ceramic brackets with metal slot seem to be a good substitute to conventional stainless-steel brackets and ceramic brackets in space closure with sliding mechanics in patients with esthetic demands.

KEY WORDS: Arch-wires, brackets, canine retraction, friction, sliding mechanics.

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INTRODUCTION

Friction is defined as the force (FR) that resists a movement when an object moves tangentially against another. As the two surfaces in contact slide against one another, several forces develop. The frictional component (FR) is directed in a tangential direction to the surfaces in contact. Normal force component (N) is directed perpendicular to the contacting surfaces. Friction is directly proportional to the normal force and described by the equation $FR = \mu N$, where μ = the coefficient of friction.[1-4]

Friction between brackets and different archwires during sliding mechanics play an important role in orthodontics, as it reduces the effectiveness of the orthodontic appliance and slows down tooth movement, so elongate treatment duration.[5-8]

The nature of friction in orthodontics is multifactorial, derived from both assembly of mechanical and biological factors.[2,9-15] Many studies have been carried out to evaluate the factors that influence frictional resistance: Bracket and arch-wire materials, surface condition of the arch-wire and the bracket slot, bracket width, arch-wire size and shape,[16-20] use of self ligating brackets, number of brackets, inter bracket distance, saliva, and influence of oral functions, etc. Surface structure of archwire, torque at the wire bracket interface, type and amount of force exerted by ligation.[21-24]

In modern society, the esthetic aspect of orthodontic therapy is important due to the number of grown persons undergoing orthodontic therapy are increasing.[17,19,25] Therefore, the development of appliance that combines both esthetic and technical performance is an important goal. Ceramic brackets were developed to improve the esthetics during orthodontic treatment; however, in clinical use, they have high frictional resistance to sliding mechanics.[18,26] Ceramic brackets with metal slot were developed to minimize the frictional characteristics of ceramics brackets.[21,23]

Coating the arch-wires have been introduced to enhance esthetics and decrease friction. These wires are premeditated to be esthetically more acceptable by the patient. They are given a plastic tooth colored coating so that it can merge with the tooth color and ceramic brackets. Coating or refining the wire surface with other materials has an influence on frictional behavior. Arch-wires with coating could probably decrease frictional resistance at the bracket arch-wire interface.[27-29]

AIM OF THE STUDY

The aim of this in vitro study was to evaluate the effect of different bracket-archwire combinations on frictional resistance during simulated canine retraction on typodont model.

MATERIALS AND METHODS

A sample of 60 first premolar teeth extracted for orthodontic purpose was used and selected on the following inclusion criteria: intact enamel, non-carious, no previous restoration and no enamel hypoplasia. The teeth collected were stored at room temperature in distilled water (Aqua Bure lab) (PH : 6.50 – 6.8) for 24 hour .

All teeth were mounted on self-cured acrylic resin block in a way that root was embedded into the acrylic just below the cemento-enamel junction level, leaving the crown fully exposed. The samples divide into three equal groups (20 for each group) prescription with 0.022 × 0.028-inch on the base of bracket material as follow:

Group 1: Pre-adjusted metal bracket (3M Unitek™ Gemini bracket)

Group 2: Pre-adjusted ceramic bracket (3M Unitek™ Clarity ADVANCED)

Group 3: Pre-adjusted ceramic bracket with metal slot (3M Unitek™ clarity metal reinforced)

In this in vitro study, each bracket incorporated with 0.022 x 0.028 slot dimensions.

Each group was subdivided into two subgroups according type of used arch-wires as follow:

Subgroup (A): 10 uncoated stainless steel 0.016X0.022-inch orthodontic arch-wires (Ortho Organizers, San Marcos, CA)

Subgroup (B): 10 Nickel titanium archwires (NiTi) (Ortho Organizers, San Marcos, CA) were used .

Ligation was performed by regular clear elastomeric module (Ortho Organizers, San Marcos, CA).Frictional resistance was measured in grams with a universal testing machine (model 2519-107, Instron, Canton, MA, USA).

Testing Model Preparation:

To simulate fixed appliance in the oral cavity a typodont testing models were prepared to mimic the maxillary jaw. (Figure 1)

For canine retraction mechanics, testing models were prepared by removing 1st premolars from their position to simulate the condition of an extraction case. The canines were cut at the level of cervical line to facilitate its distal movement during sliding mechanics over the arch-wire. (Figure 2)

On the typodont models teeth (central incisors, lateral incisors, canines, and 2nd premolars) brackets and buccal tubes (1st molars) were bonded at the clinically appropriate position using a chemical cure conventional bonding system. (Resilience,ORTHO TECHNOLOGY, Tampa, Florida, USA,).

Similarly testing models were prepared for all the combinations Brackets and arch-wires were cleaned with acetone wipe to remove any surface impurities. The arch-wires to be tested were ligated to the brackets by elastomeric module.

For all the tests, ligation was done by the same individual. The elastomeric ligature modules were placed immediately before each test to avoid ligature force decay[11].

Testing

The testing model was positioned vertically on the lower fixed member of the universal testing machine. For the movement of canine, a loop of arch wire was made and loop was engaged in the hook of canine bracket. Free end of SS wire was held by upper cross head of testing machine (instron model 2519-107). The upper cross head member of the testing machine was adjusted to move upwards at a constant speed of 0.5 mm/min.[5] Movement was started when canine was in contact with the distal surface of lateral incisor and stopped when canine just touched the mesial surface of second premolar. Total distance bracket travelled was 7 mm as recorded on computer. (Figure 3)

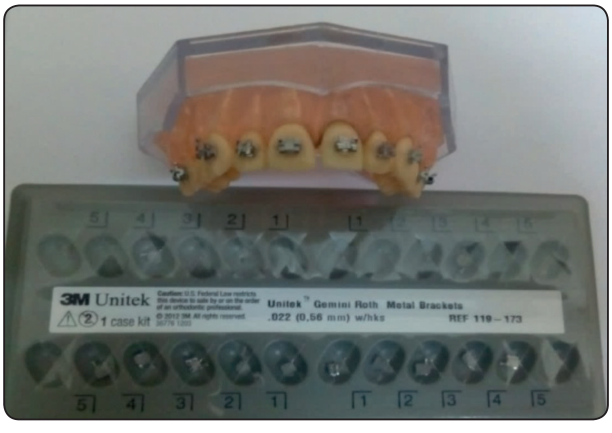

Fig. (1): Metal brackets bonded to typodont

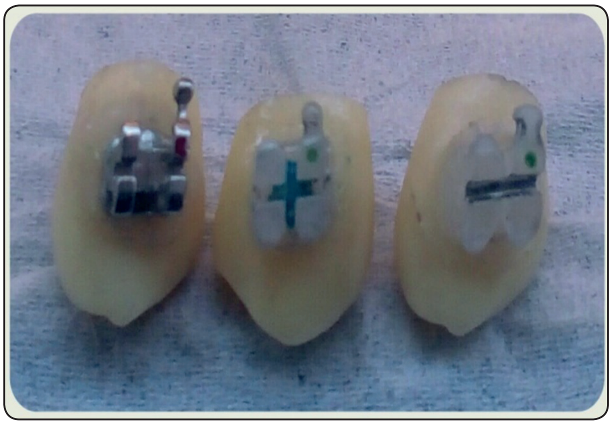

Fig. (2): Canines cut at cervical line

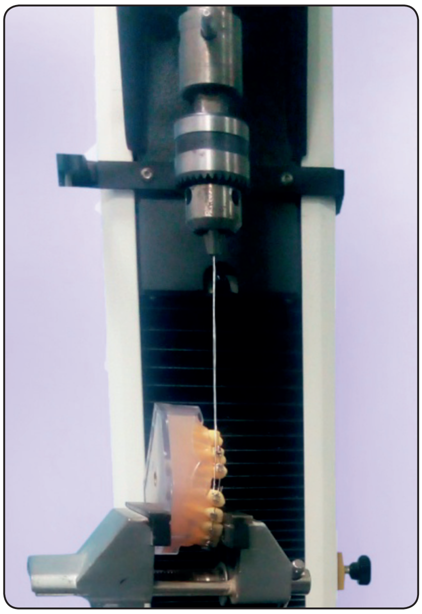

Fig. (3): Typodont mounted on instron testing machine

Statistical analysis:

The collected data revised, tabulated, and analyzed using SPSS V22.0 for Windows (SPSS Inc., Chicago, Illinois, USA). Quantitative variables were expressed as mean ± standard deviation (SD). Normal distribution of the quantitative variables was tested by Shapiro – Wilk test. Differences between independent groups were assessed by Student t-test for normally distributed quantitative. The effect of variables (bracket materials, ligation materials and arch-wires) on frictional resistance were observed and compared together by three-way analysis of variance and the significance of mean difference between the groups was done by Tukey's Post Hoc test. All results were considered statistically significant at the level of $p < 0.05$.

RESULTS

The results demonstrated that ceramic brackets showed the significantly higher frictional resistance compared with stainless steel brackets and ceramic brackets with metal slot. There was a statistically significant interaction ($P<0.0001$) between the brackets which indicates that the frictional characteristics depending on the combination used.

With all bracket types, NiTi Archwire with ceramic bracket showed the statistically significantly highest mean force. This was followed by SS with ceramic, NiTi with ceramic with metal slot, SS arch wire with ceramic with metal slot. SS Archwire with metal bracket showed the statistically significantly the lowest mean force.

TABLE (1): Mean±SD, result of ANOVA and Tukey's test for comparison between frictional resistances induced by different types of brackets with Elastomeric module ligature.

	Brackets			
	Stainless Steel	**Ceramic**	**Ceramic with metal slot**	***P* value**
Arch wires: ↓	**Mean±SD**	**Mean±SD**	**Mean±SD**	
Uncoated SS	132.25±5.70	209.9±4.6	169.45±5.56	<0.001**
NiTi	140.25±8.75	223±3.14	176±7.75	<0.001**
P value	<0.001**	<0.001**	≤0.05*	

****Significant at p ≤ 0.05***

***** Highly Significant at p ≤ 0.01***

DISCUSSION

Orthodontic tooth movement is dependent on the ability of the specialist to use controlled mechanical forces to stimulate biologic responses within the periodontium.[15-16]

The clinician should be concerned with the physical characteristics of the orthodontic appliances, wires and ligature material that contribute to the friction during sliding mechanics and to the extent of force amount expected to be reduced by friction.[3]

In the present study, the effect of three types of bracket material, and different arch-wires on frictional resistance was studied, since frictional resistance at the bracket arch-wire interface is mostly affected by these variables.

Majority of investigators used straight length arch-wire and fixed the bracket over models and draw the straight length arch-wire through the brackets in the Instron universal testing machine[16-18]. This does not fully simulate the clinical reality, because clinically moving teeth during sliding mechanics do not occur in a straight line.

The method used in the present study was designed to closely replicate the clinical situation. The present study was carried out in dry conditions; to achieve results in non contaminated conditions, as observed in many previous studies.[5,9,11]

The ceramic brackets showed the significantly higher frictional resistance (P<0.001) compared with stainless steel brackets and ceramic brackets with metal slot. A possible explanation is that ceramics have a higher coefficient of friction than stainless steel because of increased surface roughness, hardness, stiffness, and porosity of the material surface. Manufacturing process, finishing, and polishing are also difficult; this might explain the granular and pitted surface of the ceramic brackets.[19]

The ceramic bracket with metal slot showed the intermediate values of the frictional resistance, probably because its slot is braced with metal, which prevents direct contact between ceramic and arch-wire. The metal slot appears to cause the ceramic bracket to behave more like a stainless steel bracket than a conventional ceramic bracket in terms of static and kinetic frictional resistance as reported by Dickson and Jones.[20]

The difference of the frictional force rates between the ceramic bracket with the metal slot and the stainless steel brackets can be due to the difficulty in adjusting the metal to the ceramic and to their different expansion coefficients.[21]

The type of ligation has considerably influenced the frictional values. In the present study, the bracket arch-wire friction were tested immediately after ligation with elastomeric modules so not much of force decay would have occurred.[11]

Nickel-titanium arch-wires shows higher frictional resistance (P<0.001) then stainless steel arch-wires these findings were in accordance with the findings of previous studies.[21,22,24]

Stainless steel arch-wires have the smoother surface than nickel-titanium so they have less frictional resistance. NiTi arch-wires have greater surface roughness than compared with stainless steel archwires.[19,21] This result of the present study was also in agreement with the result of few previous studies.[25,26]

CONCLUSIONS

Ceramic brackets with metal slot seem to be a good substitute to conventional stainless-steel brackets in space closure with sliding mechanics in patients with esthetic demands. The highest frictional resistance was observed between Ceramic bracket and NiTi arch-wire combination ligated by Elastomeric module.

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